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LOCAL MATERIALS RAMMED EARTH IN SUSTAINABLE MANNER

Wanita Subadra Abioso, Maulana Naufal Farras

Department of Architecture, Faculty of Engineering and Information Science
Universitas Komputer Indonesia
Dipatiukur 112-116 Bandung
wanita.subadra@email.unikom.ac.id[1*]

ABSTRACT

Sustainable design indicates that one of the criterions to achieve sustainability, is working with natural resources, local material in particular. Majalengka Regency, West Java province in Indonesia that has local material terracotta (clay) wishes to build its Cultural Centre. This proposed design utilizes local material terracotta (clay) that is mixed into rammed earth due to availability of the materials. The phases of the process of utilization will be expressed according to the cradle-to-grave paradigm, well known as Life-Cycle-Assessment (LCA), a method of assessment to sustainable product. The method is action research based on design models, including the method of LCA and method of design, and many aspects of the design that would be concerning sustainable manner. The sequential phases from a to z will show how designing with local material, in this case rammed earth, according to the assessment tool, responsible for the process of extraction–forming–usage–benefit–waste disposal. This proposed design hopefully will increase the willingness of designers to adopt and apply design with local material which is rarely utilized. Hopefully, the results will be popularizing the usage of local material to achieve more sustainable design.

Keywords: LCA; sustainable; terracotta; rammed earth

INTRODUCTION

City of Jatiwangi, Majalengka Regency, West Java Province of Indonesia, well known with its local material terracotta (clay) has started to lose its famous products, *genting* (roof tile) Jatiwangi. Terracotta areas in Majalengka Regency mostly present as tile and brick factories, that

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spread across six districts: Jatiwangi, Jatipuh, Kasokandel, Dawuan, Ligung and Kertajati. The terracotta locus area is named Jajakadali Cluster. In order to cope with the very quickly changes in the northern Majalengka, the Regency and Provincial Governments will push for the Jajakadali Cluster area which is expected to involve local potential and products in development.

To prevent the further loss of terracotta usage in particular, Majalengka wish to build its Cultural Centre and planned to build the building with local material rammed earth (mixed of sand, gravel, and clay). Materials are the easiest way for architects to begin incorporating sustainable design principles in building [Hussain, 2012]. Within this context of sustainable materials for building design, earth is an ancient material that has been used in buildings until nowadays and its recovery as building material becomes more attractive when other parameters are taken into account as its low embodied energy, low price, availability and recyclability [Serrano]. Sustainable materials need to be developed and used appropriately. In addition, sustainable materials also have many advantages, for example reducing carbon emissions, minimizing global warming and also minimizing the use of materials that are not energy efficient [Hussain, 2012].

Rammed earth is a mixed soil-based wall construction of sand, gravel and clay. The quality of rammed earth walls is dense, solid, and stone-like without polluting the environment and low maintenance costs. Rammed earth has been used for about 10,000 years in all types of buildings. This construction is made from a mixture of approximately 70% aggregate (sand, gravel) and 30% clay [Diableh, 2014].

This research carried out based on action research method with model of design, besides Life Cycle Assessment (LCA) method or a cradle-to-grave tool that used to evaluate natural effects linked to all the phases in the life of the product, from obtaining of raw materials, processing materials, manufacturing, dissemination, usage, maintenance, and repair, and selling or reusing. And the last method is the design method. The result of the design hopefully will increase the willingness of designers to adopt and apply designing with natural resources especially local

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material which is rarely utilized, in other words hopefully the results will widespread the usage of local material to achieve design that is more sustainable.

METHOD

Action Research

Action research, adopted in this research is based on a model of design. Action research comprehended as a research method that aims to simultaneously investigate and solve an issue at the same time. The involved processes are: firstly, assessment process to sustainable product used cradle-to-grave tool known as Life Cycle Analysis (LCA), carried out give some result that can be immediately corrected, solved, and developed as soon as the environmental impact issued. Rammed earth material that is frequently used in District of Majalengka or utilized rammed earth, has been known for a long time in the form of soil compaction for walls. Secondly, the design process which is applied according to current conditions.

Life Cycle Assessment (L CA)

Life Cycle Assessment (LCA) is a process of scientific investigation that explores the whole-of-life environmental impacts of a product. It is a standardized platform to perform Life Cycle Costing alongside Life Cycle Assessment with great opportunity to reduce costs including environmental impacts [Petrovicab, 2018], in this case the life cycle costing was not performed. Rammed earth is considered a product. LCA conducted to get a better understanding of the product's hidden environmental impacts (Abioso and Afrianto, 2013), see figure 1.

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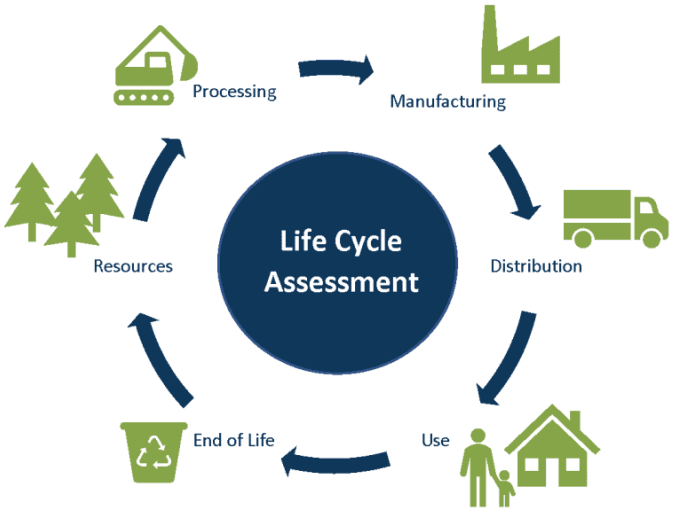

Figure 1. The Diagram of Life Cycle Assessment (LCA) based on cradle to grave paradigm

Source: https://textilelearner.net/life-cycle-assessment-of-your-clothes/

- Material extraction (where did the materials come from?). Utilized rammed earth material, mixed of sand, gravel, and terracotta known as clay, and all aggregates provided from the area of Majalengka Regency.
- Manufacturing (mixed compacted walls, what was the process of construction of creating the product from the raw materials?). Rammed earth in Majalengka Regency usually mixed manually without using heavy equipment.
- Packaging and transport (how are they packaged and transported from place of manufacturing to point of sale?). Rammed earth in Majalengka was produced manually and locally, as a product of home industries.
- Use (this phase is to know what is the lifespan and use of the product?). Rammed earth is considered as nature friendly materials with long lifespan, even though nowadays frequently supported by additional aggregate such as concrete but this will produce CO_2 as negative environmental impact.

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- End of life: this phase is to know how the product is handled at the end of life? (Disposable, recyclable, or is it reusable). In the end of life, the rammed earth will remain to be mixed material of building construction. The value of the end of life concerning environmental impact create certain thermal comfort, either inside or outside the building.

RESULT AND DISCUSSION

Design Method

The building design process adopt some methods that suitable for the kind of approach in order to fulfil the nature of design with local material. The design method consists of some phases including planning and programming, problem seeking and solving through theme and design concept, and the design as a result. Planning and programming phase will embrace data collection, data analysis, data synthesis including reveal theme and some design concepts. The significant data collected s: terracotta, rammed earth, the height of the wall, climate, strength, etc. A true work of architecture, expresses a singular theme that integrates all aspects of piece into one coherent whole. Without this thematic integrity, a work is merely a conglomeration of parts which lack of power [Abioso, 2021]. The theme of this design is sustainable local material, therefore most of design concept, to solve the problems and develop the potencies, will emanate from the theme. Figure 2 shows the result and discussion on the design utilized rammed earth construction for Cultural Centre in Majalengka Regency.

In term of building function, rammed earth construction can be utilized in the form of forts, places of worship, residences, settlements, schools, universities, community centre, factories and many others.

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Figure 2. Site Configuration of Pusat Budaya Terakota
(Terracota Cultural Centre)

Source: Faras (2020)

Site Configuration

The construction of the Cultural Centre, Majalengka regency, West Java province, utilized rammed earth (mixed of gravel, sands, and terracotta known as clay) as the most used material of wall structure. Rammed earth will be best utilized in tropical area, since the drying of the material depends on the sunlight. The average temperature in Majalengka regency reach 27º C. The design configuration above considering all rammed earth characteristics, especially the drying and hardening process of the rammed earth that depends on the sunlight, so that the configuration fully exposed to the sunlight. Sustainable design minimizes the harmful effects of construction projects on human health and the environment, so that the design should be referred to this [Diableh, 2014]. One of the positive environmental impacts of this construction is the creation of certain thermal comfort either inside or outside the building, acting as outdoor air conditioning created by a bunch of vegetation (see figure 3 and 4).

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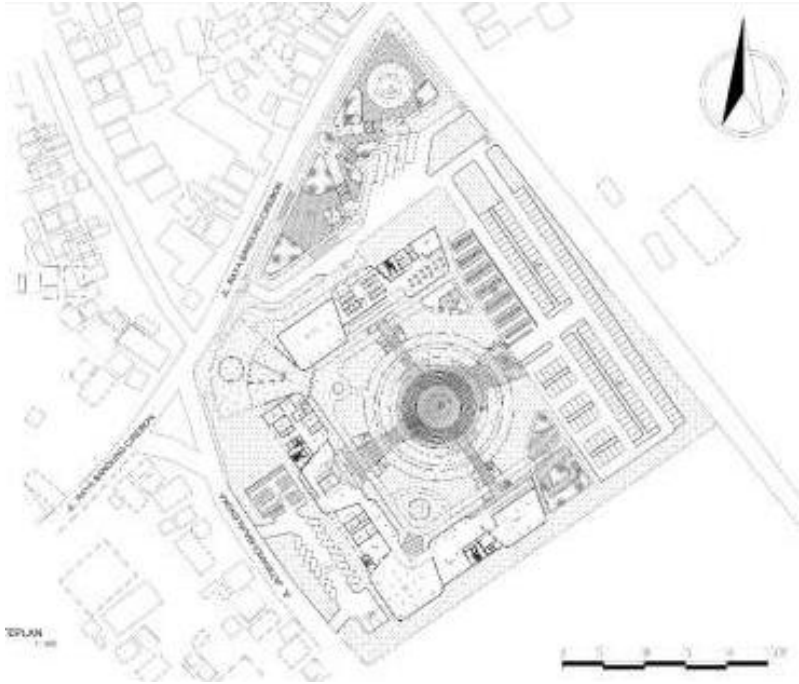

Figure 3. Site Plan of Pusat Budaya Terakota (Terracota Cultural Centre)

Source: Faras (2020)

Figure 4. Elevation of Pusat Budaya Terakota (Terracota Cultural Centre)
Source: Faras (2020)

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Structure And Construction

The resulting structure can withstand compressive strengths of up to 2.5 megapascals (about 10% of the average compressive strength of modern bricks) [Niroumand, 2014]. The walls of the cultural centre are planned, that the material will be compacted in the formwork that will be removed after the mixture dried and hardened. Rammed earth walls are constructed by ramming a mixture of selected aggregates, including gravel, sand, silt, and a small amount of clay, into place between flat panels called formwork. Traditional technology repeatedly rammed the end of a wooden pole into the earth mixture to compress it. (see Figure 5)

Wall

Most of the walls in the building construction of the cultural centre utilized the rammed earth. This material was chosen considered that the location of the cultural centre has a fairly hot air temperature. The cultural centre needs material that has the ability to breathe and also has good thermal comfort. The use of rammed earth material is very suitable for the environmental characteristics of the site of the cultural centre. About 5–10 inches wet sub–soil mixture is placed in the form and thoroughly beaten compaction and the process will be repeated until the desired height is reached, the height of the buildings is the height of two floors construction, 7,20 m (see Figure. 5) Rammed earth construction is usually associated with a "build it yourself" program of construction in which earth, the building material, costs nothing, and in which the owner provides much of the labor of construction. {DeLong, 1959}

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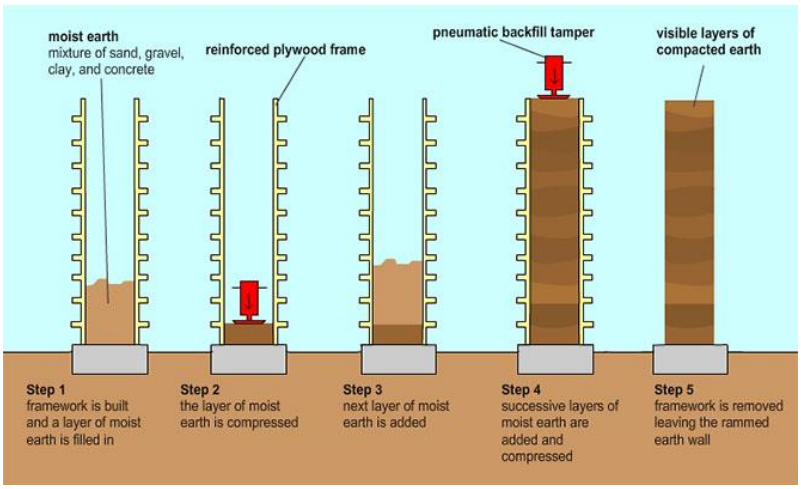

Figure 5. Construction Steps of Rammed Earth.
Source: Niroumand (2014)

Fire Protection

Apart from being used as a breathable wall in the design of the cultural centre, the rammed earth wall is also used for fire protection. Rammed earth material has better fire resistance than ordinary walls. Therefore, in the design of the cultural centre the walls used for the fire ladder are made of rammed earth material. Rammed earth is recommended material for areas prone to forest fires. Meets fire zone requirements with a fire rating of 4 hours. Rammed earth has excellent soundproofing and acoustic capabilities and also termite resistant.

Rammed earth has an interesting colour that produced from the compacted soil layer and also has a low carbon emission. The rammed earth construction of the buildings of cultural centre utilized natural colour without any additional aggregate, though sometimes cement added if eeded mix or pigmentation to achieve the desired colour. The construction of cultural centre finished by earth plaster (see Figure 5 and Figure 6) [Suhamad and Martana, 2020].

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Energy Saving

Equipment of the construction also uses less energy to build. To gain the optimum advantages in regard with temperature and humidity, the buildings using earth plaster and no painting or maintenance required. The buildings can control humidity, humidity in Jatiwangi is about 32%, through the natural ability of walls to absorb and release moisture. It can make permanent energy savings because it can control temperature well. While there are several techniques available to regulate humidity, one effective and often overlooked strategy is incorporating thermal mass into the building's design. It will explore the concept of thermal mass, its advantages for humidity control, and how it can be effectively incorporated into a building, {Dejeant, 2021} Thermal mass refers to the ability of a material to absorb, store, and release heat. Materials with high thermal mass, such as concrete, stone, or brick, have the capacity to store heat energy for extended periods. When the temperature drops, this stored heat is gradually released, acting as a buffer and regulating indoor temperatures. Similarly, in humid conditions, thermal mass can also absorb moisture vapor and release it when the humidity decreases, thereby controlling the moisture levels within a space [Serrano, n,a],

Figure 6. Interior Design of Pusat Budaya Terakota
(Terracota Cultural Centre)
Source: Faras (2020)

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Figure 7. Exterior Design of Pusat Budaya Terakota (Terracota Cultural Centre)
Source: Faras (2020)

CONCLUSION

Utilizing natural resources, local material in particular, in this case terracotta (clay) mixed into rammed earth (sand, gravel and clay), in building construction considered as building with sustainable manner. This kind of approach has advantages, that the process of assessment on the rammed earth as sustainable product can be carried out immediately by tools based on cradle-to-grave paradigm well known as Life Cycle Assessment (LCA), in order to know the environmental impacts occurred. Overall assessment phases, since the cradle to the grave phase can be performed so that the environmental impacts can give awareness that the so-called utilized material need to be either evaluated or proceed. The results shows that the design process holds optimizing utilization of local material benefits. Benefits relates are, nature friendly (the mixtures of sands, gravel, and clay), outdoor air conditioning, natural colour and cost reduction. In the context of cultural legacy, fortunately Majalengka Regency has been paid highly attention to terracotta. Designing by utilizing local material, hopefully will popularize the usage. The sustainability in this model of design showed, i.e. the sustainability of local material assessed by LCA, less additional heavy equipment, cost and distance reduction, low

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carbon emission. Some matters concerning rammed earth that need further thoughts are: limitation to the height of the wall, dependency to climate due to drying and hardening process, takes time manually mixing, and additional material such concrete that not merely to gain certain colour but frequently for reinforcement, this unfortunately give negative impact to environment by increase carbon emission.

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